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THREAT LAUNCH DETECTION SYSTEM AND METHOD

STATEMENT OF GOVERNMENT INTEREST

[1] The invention was made with United States Government support under Contract (Grant) No. DMEA90-99-D-007 awarded by DMEA. The United States Government has certain rights in this invention.

CROSS-REFERENCE TO RELATED APPLCIATIONS

[2] The present application is a national phase application filed pursuant to 35 USC § 371 of International Patent Application Serial No. PCT/US2005/003811, filed 7 February 2005; which claims the benefit of United States Provisional Application Serial No. 60/542,042, filed 5 February 2004, now expired; all of the foregoing applications are incorporated herein by reference herein in their entireties.

TECHNICAL FIELD

[3] The present invention relates generally to sensors and more particularly to threat warning detectors for short-burn and motorless threats such as tube launched missiles and direct fire projectiles.

BACKGROUND OF THE INVENTION

[4] A threat launch detection system is a system that detects a weapon that is being directed at a target, with the target typically containing the threat launch detection system. In response to detecting a weapon directed at the target, which will be referred to as a threat or event throughout the present description, the threat launch detection system typically takes countermeasures to prevent the weapon from impacting the target. For example, an airplane may include a threat launch detection system designed to detect missiles fired at the airplane. When the system detects a

missile, the system typically takes appropriate countermeasures in an attempt to prevent the missile from impacting the airplane, such as transmitting a signal to "jam" the seeker of the missile.

[5] Different types of targets, which may be referred to as military vehicles in the following description, face different types of threats. Airplanes as previously mentioned face the threat of guided missiles, which may be "heat seeking" or infrared (IR) guided or radar guided missiles. Such missiles include engines or rockets that propel the missile through the air towards the airplane. Such a rocket continually burns to propel the missile and threat launch detection systems in aircraft exploit this fact to detect such threats. Other types of military vehicles, such as helicopters and tanks, face different types of threats. For example, a tank faces the threats of being shot at by a rocket propelled grenade (RPG), a shell from another tank, or any of a variety of other antitank weapons.

[6] Threats such as a shell from another tank or an RPG are examples of what are known as "short-burn", "motorless," or "post-burnout" threats. These threats are so named because the charge or engine utilized to propel the threat is active for only a very short time when compared to other types of threats such as guided missiles. In the following description, such threats will be referred to simply as "short-burn" threats. As a result of the different characteristics of different types of threats, threat launch detection systems must be capable of detecting the types of threats most likely to be encountered by the type of military vehicle containing the system or the type of vehicle the system is designed to protect.

[7] To detect these various types of threats, conventional threat launch detection systems utilize sensors formed by a sensor array in combination with suitable optics that provide a desired field of view (FOV) for the sensor. The field of view is the area that is sensed by the sensor. Such sensor arrays may be formed from infrared (IR), electro-optic (EO), or ultraviolet (UV) types of individual sensors. Such sensor arrays typically capture images at a rate of about 100 Hz and processing circuitry in the threat launch detection system analyzes the captured images to detect a threat. These

sensor arrays are relatively small and to provide a good field of view for each sensor the focal length of the associated optics must be relatively small (i.e., as the focal length decreases the field of view increases). The focal length must be kept to a reasonable value and therefore the field of view of a typical sensor array is relatively narrow, meaning that a lot of sensor arrays are needed to provide the overall field of view required by the threat launch detection system.

[8] In operation, each sensor captures images in its corresponding field of view and the processing circuitry analyzes successive images or frames. The processing circuitry detects threats based on the differences from one frame to another. By comparing frames and analyzing in which pixel or pixels of the sensor array the threat occurred, the processing circuitry determines when the threat was fired. The term "pixel" as used herein refers generally to one of the individual sensor elements contained in a sensor array, with the sensor elements being arranged in rows and columns to collectively form the sensor array. The processing circuitry also determines the direction of detected threat from which one or ones of the sensor arrays detected the threat and the distance of the threat from the detected intensity.

[9] These sensor arrays and the associated processing utilize what may be termed "spatial tracking" to detect threats. In spatial tracking, the pixels in a given frame are analyzed relative to the pixels in adjacent frames as just described. The position of pixels in each frame that detect some image change from frame to frame as the threat moves through space, hence the term spatial tracking. The processing in spatial tracking typically involves track processing, a form of pattern recognition as part of the detection of a threat, as will be appreciated by those skilled in the art.

[10] These conventional threat launch detection systems utilizing IR, EO, and/or UV sensor arrays are best suited to detecting threats having relatively long durations, such as the powered fly out of a guided missile. This is true partially because the time for acquisition and processing required to analyze the frames captured by each sensor array is relatively intensive, and, as previously mentioned, numerous sensor arrays are required to provide the required overall field of view for the system. Each of these

sensor arrays has numerous pixels, and the processing circuitry must separately read and analyze the data of each pixel for each array.

[11] This intensive processing caused by the multiple sensor arrays and the large number of pixels per sensor array limits the rate at which the system can operate and thereby limits the types of threats that can be reliably detected. Short-burn threats such as tank shells or RPGs are accordingly not reliably detected by conventional threat launch detection systems. It should also be noted that a key operational characteristic of threat launch detection systems is the elimination of false detections. To do so the system typically compares three to five or more successive frames from each sensor array and analyzes the pixels to ensure the threat is present in the same pixels or pixels in each of these frames. If the threat is of sufficient duration that it is present in these pixels for successive frames then a threat is detected. If the threat is not present in each of these frames, however, such as may be the case for short-burn type threats where the threat may only be present in one or two frames, the system determines the threat is false. With these conventional threat launch detection systems, even though a real threat such as an RPG has been directed at the target containing the system, the systems have problems reliably detecting the short-burn threat.

[12] To detect the launch of short-burn threats, conventional threat launch detection systems typically utilize IR and EO sensors operating in one or two midwave infrared bands (3-5 micron wavelength). UV sensors have also been utilized in such systems as previously mentioned. Weapons have been designed for deployment via short-burn to reduce the duration of the observability of the threat and thus prevent the system from detecting the threat. Thus, although the sensors typically "see" the threat, meaning at least some pixels in at least one sensor detect the presence of the threat, the processing of these pixels does not detect the short-burn threat.

[13] In an attempt to more reliably detect short-burn threats, some systems have attempted to perform "temporal profiling" of the frames captured by the IR, EO and UV sensor arrays. In temporal profiling, the individual pixels are analyzed over time rather

than relative to other pixels as is the case in spatial tracking. Attempts at temporal profiling have been unsuccessful for a variety of different reasons. First, as previously discussed these sensors have insufficiency of sampling rate issues, namely the rate at which the sensor arrays capture images is too slow relative to the duration of short-burn threats. Additionally, the dynamic range (i.e., the range of detectable signals from the weakest to the strongest) of these sensor arrays is insufficient to reliably detect all the various types of short-burn threats.

[14] These sensor arrays also have loss sharing issues, meaning that the threat is detected or "shared" by multiple pixels over time. This makes reliable analysis of these pixels over time or temporal profiling extremely difficult. Even sub pixel sized threats will form images that can fall on several pixels in a sensor array due to finite optics spot size. Any line of sight motion, whether due to movement of the threat or movement of the sensor base, changes the distribution of pixels on which threat falls. This may be termed sharing noise, and this sharing noise scales with the instantaneous amplitude of the signal detected by a given pixel, making it problematic regardless of how strong the signal. To obtain accurate intensity of signal information, the processing circuitry must determine where the signal is located and then estimate the nearby background to correct for this effect. This background is difficult to accurately estimate without performing hundreds or more calculations per pixel. This calculation is useful only when the pixels can be corrected for offset and gain variation, adding a requirement that a focal plane of the sensor and associated drive electronics be very stable electronically. Those skilled in the art will appreciate that offset error decreases in significance with increased signal but gain error scales with signal input.

[15] There is a need for a threat launch detection system and method that can reliably detect various types of short-burn threats.

SUMMARY OF THE INVENTION

[16] According to one aspect of the present invention, a threat launch detection system includes at least one temporal threat detector, each temporal threat detector including a single sensing element operable to sense radiation from various types of short-burn threats that occur within a field of view of the detector. The single sensing element generates a detection signal in response to the sensed radiation. A processing circuit is coupled to each temporal threat detector and is operable to analyze the detection signal from each detector as a function of time to detect the occurrence of a short-burn threat within the field of view of any of the temporal threat detectors.

[17] Each temporal threat detector may be a prism-coupled compound parabolic concentrator (PCCP). Alternatively, each temporal threat detector may include a single sensor element and suitable optics for directing radiation within the field of view onto the sensor element. The threat launch detection system may further include a number of sensor arrays, with the processing circuitry operable in response to detecting the occurrence of a short-burn threat to process signals from the sensor arrays to more precisely identify a location of the short-burn threat relative to the system.

BRIEF DESCRIPTION OF THE DRAWINGS

[18] **FIG. 1** is a graph showing irradiance as a function of time for various types of short-burn threats and clutter;

[19] **FIG. 2** is a schematic block diagram of a threat launch detection system according to one embodiment of the present invention;

[20] **FIG. 3** is a vertical cross-sectional schematic view of a prism-coupled compound parabolic concentrator embodiment of one of the temporal threat detectors of **FIG. 2** according to one embodiment of the present invention;

[21] **FIG. 4** is a schematic block diagram of a threat launch detection system including a number of threat detectors including optics in combination with a sensor

array and a temporal sensor according to another embodiment of the present invention; and

[22] **FIG. 5** is a vertical cross sectional schematic diagram showing one embodiment of the threat detector of **FIG. 4**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

[23] Before describing several embodiments of the present invention, the characteristics of several types of short-burn threats will be discussed with reference to **FIG. 1. FIG. 1** is a graph showing irradiance as a function of time for various types of short-burn threats and clutter. Various short-burn threats and threat like events on the battlefield are distinct when observed or sensed at a frequency of 1000 Hz or above. **FIG. 1** shows a sampling of such threats as measured by a fast radiometer, including several antitank guided missile time sequences with direct fire gun blasts, indirect fire artillery, warhead events, and machine gun fire. These sequences are all measured data from events at various distances from the radiometer.

[24] **FIG. 1** shows that a sensor capable of distinguishing threats would need a minimum of 20 pw/cm^2 sensitivity and a top end of about 2 x 10^{-6} or about 1x10^5:1 dynamic range. The figure illustrates that temporal profiling to distinguish typical short-burn threats such as tank main gun fire and missile launches from detonations, artillery muzzle flashes, and machine gun fire is possible due to the differing temporal signals generated by such threats. For example, the machine gun and artillery muzzle flashes are much shorter than the tank main gun and missile launch signals. Similarly, the detonation of a 120 mm artillery shell lasts much longer than the tank main gun and missile launch threats of interest. In **FIG. 1**, the detonation of a 120 mm artillery shell is an example of a clutter event not to be detected as a threat.

[25] In the following description, certain details are set forth in conjunction with the described embodiments of the present invention to provide a sufficient understanding of the invention. One skilled in the art will appreciate, however, that the invention may

be practiced without these particular details. Furthermore, one skilled in the art will appreciate that the example embodiments described below do not limit the scope of the present invention, and will also understand that various modifications, equivalents, and combinations of the disclosed embodiments and components of such embodiments are within the scope of the present invention. Embodiments including fewer than all the components of any of the respective described embodiments may also be within the scope of the present invention although not expressly described in detail below. Also, the operation of well known components and/or processes has not been shown or described in detail below to avoid unnecessarily obscuring the present invention. It should also be noted that in the figures and following description, references assigned to multiple components of the same kind include both numbers and letters, and that both the number and letter are utilized when referring to a specific one of these components and only the number is used when referring generally to any or all of such components.

[26] **FIG. 2** is a schematic block diagram of a threat launch detection system ***200*** according to one embodiment of the present invention. The threat launch detection system ***200*** includes a number of temporal threat detectors ***202a***, three of which ***202a-c*** are shown in **FIG. 2**. Each temporal threat detector ***202a-c*** has an associated field of view (FOV) as shown and includes a structure that captures a significant portion of the radiation generated by a short-burn threat SBT such as tank main gun fire within the field of view, as shown for the temporal threat detector 202a in Figure 2. A single sensor element (not shown) within each temporal threat detector ***202a-c*** senses the captured radiation and generates a corresponding detection signal in response to the sensed radiation.

[27] The field of view of each temporal threat detector ***202a-c*** is ideally relatively wide so that a small number of detectors are needed to sense the required overall region surrounding the system ***200***. For example, if each temporal threat detector ***202a-c*** has a field of view of approximately 90 degrees, then four detectors are required to provide sensing of the entire 360 degrees surrounding the system ***200*** in

horizontal plane. Note that in contrast to the sensor arrays previously described, each of the temporal threat detectors ***202a-c*** is a very low resolution sensor, containing only a single sensing element for a relatively wide field of view. Thus, each of the temporal threat detectors ***202a-c*** functions to provide a detection signal indicative of the occurrence of a short-burn threat but the precise location of the threat within the relatively wide field of view is not known, as will be discussed in more detail below.

[28] The detection signal from each temporal threat detector ***202a-c*** is applied to a corresponding bias and amplifier circuit ***204a-c*** which biases and amplifies the received detection signal to thereby generate a corresponding conditioned detection signal. A multiplexing analog-to-digital (A/D) converter ***206*** sequentially digitizes the conditioned detection signal from each of the bias and amplifier circuits ***204a-c***. In digitizing each conditioned detection signal, the A/D converter ***206*** samples each signal and stores the samples in a corresponding buffer (not shown) within the converter. The A/D converter ***206*** first digitizes the conditioned detection signal from the bias and amplifier circuit ***204a***, then digitizes the conditioned detection signal from the circuit ***204b***, and then the signal from the circuit ***204c***, and so on for each conditioned detection signal applied to the converter. The A/D converter ***206*** continuously cycles through each of the applied conditioned detection signals and digitizes each such signal once during a cycle time of the converter.

[29] A fusion processing circuit ***208*** retrieves the samples stored in each buffer (not shown) in the A/D converter ***206*** and processes these samples to determine whether the corresponding detection signal indicates a short-burn threat has occurred within the field of view of the corresponding temporal threat detector ***202a-c***. Referring back to **FIG. 1**, the fusion processing circuit ***208*** need merely detect a rise and a fall of a pulse having a relatively short duration to detect the desired short-burn threats. In doing so, the fusion processing circuit ***208*** is analyzing characteristics of the corresponding detection signal over time and in this way is determining a temporal profile of the signal. In one embodiment, the fusion processing circuit ***208*** includes a temporal template for each short-burn threat to be detected. Other methods include

basis set development and eigenvector computation. The fusion processing circuit ***208*** compares each detection signal to each of the templates or eigenvectors and determines a short-burn threat exists when the detection signal approximately matches one of the temporal templates. One skilled in the art will appreciate other techniques that the fusion processing circuit ***208*** may utilize in processing each of the detection signals to determine whether a short-burn threat has occurred.

[30] When the fusion processing circuit ***208*** detects a short-burn threat has occurred, the circuit assigns a number of parameters to the detected threat. First, the circuit ***208*** assigns a timestamp to the threat indicating when the threat started. The circuit ***200*** and also assigns a type indicator to the threat indicating the type of short-burn threat detected and assigns an identifier indicating which of the temporal threat detectors ***202a-c*** detected the threat. In this way, the identifier indicates within which field of view the detected short-burn threat occurred.

[31] Once the fusion processing circuit ***208*** detects a threat and assigns the associated parameters, the circuit processes signals from sensor arrays ***210*** to more precisely identify the location of the threat relative to the system ***200***. The sensor arrays ***210*** are conventional IR, EO, and/or UV type sensor arrays as previously described. To more precisely identify the location of the threat, the fusion processing circuit ***208*** analyzes the images captured by the appropriate ones of the sensor arrays ***210***. More specifically, the fusion processing circuit ***208*** analyzes images captured by sensor arrays ***210*** having fields of view that overlap the field of view of the temporal threat detector ***202a-c*** that sensed the detected threat. For example, the fusion processing circuit ***208*** may compare two images from the appropriate sensor array ***210*** that were captured nearest in time to the timestamp parameter assigned to the detected threat.

[32] In comparing these two images, the circuit ***208*** subtracts the values of pixels in these adjacent images to thereby more precisely identify the location of the threat. The threat manifests itself in this situation as a relatively large difference in the values associated with pixels that sense the threat while the differences between other pixels

not sensing the threat will be zero or negligible between the adjacent images, as will be understood by those skilled in the art. This allows for improved clutter rejection by using the detection signals from the temporal threat detectors ***202*** to instruct the fusion processing circuit ***208*** to subtract an immediate previous frame from a frame that shows the short-burn threat based upon the determined timestamp.

[33] Once the fusion processing circuit ***208*** has more precisely identified the location of the threat, this information is applied to a countermeasure controller ***212***. This information includes the time, location, and type of short-burn threat detected. With this information, the countermeasure controller ***212*** takes the appropriate countermeasures to protect the military vehicle containing the threat launch detection system ***200***. For example, such countermeasures may include radio frequency (RF) countermeasures or IR countermeasures such as releasing smoke or ejecting a flare. Note that the information about the type of detected short-burn threat allows the countermeasure controller ***212*** to take a wider range of countermeasures aimed at thwarting the detected threat. For example, where the detected short-burn threat is an RPG the countermeasure controller ***212*** may direct fire at the RPG in an attempt to explode the RPG before it impacts the military vehicle. The fusion processing circuit ***208*** is so named because the circuit combines or "fuses" information regarding short-burn threats sensed by the temporal threat detectors ***202a-c*** with spatial tracking information sensed by the sensor arrays ***210*** to thereby allow the countermeasure controller ***212*** to take more sophisticated countermeasures in response to the detected threat.

[34] With the system ***200***, there are a relatively few temporal threat detectors ***202a-c*** and thus the processing demand on the converter ***206*** and fusion processing circuit ***208*** to operate even at 1000 samples per second is relatively low. Moreover, a military vehicle can practically be protected over a full hemisphere with as few as temporal threat detectors ***202***. In this situation, the sampling data rate that the fusion processing circuit ***208*** must process is only about 6000 samples per second at 1000 Hz compared to 100,000,000 samples per second for a staring array at one tenth the sampling rate.

Note that although each temporal threat detector ***202a-c*** is described as including a single sensor element (not shown), a sensor array could also be used with the pixels being summed together to get a single pixel value corresponding to the detection signal. The use of an array may not be practical in some situations, however, since each pixel would still need to be read from the array. This would adversely increase the processing burden on the circuit ***208*** and/or cause a reduction in the rate at which data can be read from the array, possibly limiting the practicality of using such a sensor array. Also note that the system ***200*** need not include the sensor arrays ***210***. In another embodiment of the system ***200***, the sensor arrays ***210*** are omitted and the temporal threat detectors ***202*** and other components operate only to detect short-burn threats and to take appropriate countermeasures in response to any such detected threats.

[35] **FIG. 3** is a vertical cross-sectional schematic view of a prism-coupled compound parabolic concentrator (PCCP) ***300*** corresponding to one embodiment of any of the individual temporal threat detectors ***202a-c*** of **FIG. 2** according to one embodiment of the present invention. A suitable embodiment of the PCCP ***300*** is disclosed in "PRISM-COUPLED COMPOUND PARABOLA: A NEW IDEAL AND OPTIMAL SOLAR CONCENTRATOR", L. R. Edmonds, Optics Letters, Vol. 11, No. 8, August 1986, which is incorporated herein by reference.

[36] The PCCP ***300*** includes a compound parabolic concentrator (CPC) ***302*** having a focal point F. Ideally, the CPC ***302*** "collects" all radiation incident upon the CPC within a maximum angle of radiation θ_m of a normal axis ***304***. The CPC ***302*** collects all incident radiation within the maximum angle θ_m in that all radiation within this angle is reflected off the parabolic surface 306 below the focal point F of the CPC ***302***. A prism ***310*** is positioned with its apex at the focal point F of the CPC ***302***. All radiation incident upon the CPC ***302*** within the maximum angle θ_m is thus directed onto the prism ***310***, which is designed so that all of this radiation incident upon the prism is directed to the base of the prism through total internal reflection. A sensor ***312*** is attached to the base of the prism ***310*** to sense the collected radiation. In response to

the collected radiation incident upon the sensor ***312***, the sensor generates a detection signal corresponding to the detection signals previously discussed with reference to the temporal threat detectors ***202a-c*** of **FIG. 1**. A protective window ***314*** is mounted to cover an aperture formed at an end of the parabolic surface ***306*** opposite the end at which the prism ***310*** is positioned.

[37] The PCCP ***300*** has a concentration ratio or factor C given by the following equation:

$$C = \frac{n^2}{\sin^2 \theta_m} \quad \bullet \quad \text{Equation 1}$$

where n is an index of refraction of the prism ***310*** and θ_m once again is the maximum angle of radiation collected by the concentrator. The concentration factor C is the ratio of the input aperture of the CPC ***302*** to the area of the detector ***312***.

[38] For the midwave infrared spectrum (3-5 microns), the prism ***310*** is formed from silicon in one embodiment of the PCCP ***300***. Silicon is utilized due to its high quality, high index of refraction (3.4), and relatively low cost. In this embodiment, the PCCP has a value of C of about 20:1 for a ±45 degrees for the maximum angle of radiation θ_m. In this embodiment, antireflection coatings may be formed on the protective window ***314***, prism ***310***, and interface between the prism and sensor ***312*** mounted at the base of the prism. In another embodiment, the prism ***310*** is germanium and the PCCP ***300*** operates in the long wave or thermal infrared band of 7.5 to 12 microns. In a further embodiment, the PCCP ***300*** operates as an EO band device in which the prism is plastic or high index glass and the sensor ***312*** is a silicon device. With this embodiment, more PCCPs ***300*** would be needed for the system ***200*** (**FIG. 2**) since reasonable values for the concentration ratio C limits this embodiment of the PCCP to relatively narrow fields of view. For an index of refraction of n=1.8, a field of view of ±43 degrees is possible with a 20:1 concentration ratio C. This embodiment of the PCCP ***300*** may be particularly useful for enhancing the capability and functionality of existing threat launch detection systems such as UV and IR missile launch detectors.

[39] **FIG. 4** is a schematic block diagram of a threat launch detection system ***400*** including a number of threat detectors ***402***, one of which is shown. In this embodiment, each of the threat detectors ***402*** includes suitable optics ***404*** for directing incident radiation within a field of view (FOV) onto a single element temporal sensor ***406*** and onto a sensor array ***408***. The sensor array ***408*** is positioned at a focal point of the optics ***404***. The single element temporal sensor ***406*** and sensor array ***408*** may be physically mounted or sandwiched together or simply mounted near one another. The single element temporal sensor ***406*** operates at a shorter wavelength than the sensor array ***408***, which allows radiation from the optics ***404*** at the wavelength of the sensor array to pass through the single element temporal sensor on its way to the sensor array. Note that the single element temporal sensor ***406*** does not require that the radiation from the optics ***404*** be focused on this sensor, which allows the optics to be optimized solely for the sensor array ***408***. This is also the reason the temporal sensor ***406*** and array ***408*** need not be mounted any closer together than is appropriate. The threat detector ***402*** thus combines the single element temporal sensor ***406*** that develops a detection signal that various over time in response to short-burn threats within the field of view and the sensor array ***408*** that operates as previously described for such arrays to capture images that allow spatial tracking to identify other types of threats within the field of view.

[40] The detection signal from the temporal sensor ***406*** is applied to a bias and amplifier circuit ***410***, which operates in the same way as the bias and amplifier circuits ***204*** previously described with reference to **FIG. 4** to generate a conditioned detection signal. A multiplexing A/D converter ***412*** receives the conditioned detection signal from each threat detector ***402***, and this converter operates in combination with a fusion processing circuit ***414*** and countermeasure controller ***416*** in the same way as previously described for the corresponding components ***206***, ***208***, and ***212*** of **FIG. 2**. For the sake of brevity the operation of the components ***410-416*** will not again be described in detail.

Substitute Specification – Redline Format

[41] The pixels corresponding to the images captured by the sensor array ***408*** are supplied to a staring-array processor ***418*** which processes successive captured images to detect various types of threats, such as launch of guided missile. The staring-array processor ***418*** supplies information about detected threats to the fusion processing circuit ***414***, which combines this information with information regarding short-burn threats that the fusion processing circuit generates using the digitized detection signals from the temporal sensor ***406*** that are supplied to the fusion processing circuit via the A/D converter ***412***. In response to this processing, the fusion processing circuit ***414*** provides information to the countermeasure controller ***416*** that allows the controller to implement appropriate countermeasures based upon the detected threats.

[42] **FIG. 5** is a vertical cross sectional schematic diagram showing an embodiment of a threat detector ***500*** that may be used in place of the threat detector ***402*** of **FIG. 4**. The threat detector ***500*** is another embodiment of threat detector ***402*** in which the single element temporal sensor ***406*** is positioned in front of the focal point plane F of the optics ***402***. The single element temporal sensor ***406*** need not be positioned in the focal plane F for proper operation since focus is not a concern with this sensor. Thus, the threat detector ***500*** is similar to the threat detector ***402***, being different only in the positioning of the sensor ***406*** in front of the focal plane F whereas the temporal sensor ***406*** is positioned adjoining the array ***408*** in the threat detector ***402***. In another embodiment of the threat detector ***402*** or ***500***, the detector includes a beam splitter to separate a temporal channel of incident radiation from a spatial channel of radiation. Such an embodiment is useful when the sensor array ***408*** is a cryogenic array.

[43] Those skilled in the art will appreciate that the described temporal profiling compliments existing technologies by adding a new observable capability, namely the temporal profiling of high intensity short-burn threats. This provides threat identification and ranging capability to assist conventional sensor arrays in detecting and tracking threats, many of which such arrays could "see" but would not normally detect as a threat. It will also be appreciated that the temporal profiling is very difficult to

implement using sensor arrays. Short-burn threats typically last 15 to 100 ms, making them difficult to sample at typical video frame rates inherent with the use of sensor arrays. Moreover, line of sight motion during these events of the order of 1/10 pixel can corrupt the output of a single pixel in the array. This corruption is due to the signal spot corresponding to the threat falling on a several pixels which share the total signal. Correcting for this requires considerable signal processing particularly in complex bright backgrounds. A single channel covering a wide field of view collects sufficient samples, without sharing, to be able to identify short-burn threats. Combining a temporal channel with an imaging sensor or sensor array solves the tracking and countermeasure effectiveness problems for the tracker while the temporal channel enables the imaging sensor to rapidly type new tracks and identify others with signal to noise levels too low for its stand-alone recognition algorithms.

[44] Embodiments of the present invention allow for system robustness by virtue of two complimentary detection approaches with much less complexity than current and pending multi spectral imaging systems. Embodiments of the present invention also allow for elimination of the adverse tradeoff of frame rate as required for discrimination versus sensitivity as required for many threats. This tradeoff is not significant for some cryogenically cooled sensors, which are more sensitive than threat warning requires at high frame rates. However, some cryogenically cooled devices such as quantum well infrared photodetectors ("QWIPs) are near the limit and would benefit from longer integration time. This new approach enables uncooled devices to take advantage of temporal profiling with frame rates well suited to their optimum performance.

[45] One skilled in the art will also be understood that the embodiments of this invention can also be used to augment artillery fire finder radar by eliminating transmission until incoming fire occurs. The type of fire can be recognized to thereby reduce search volume. Enemy artillery can no longer easily locate the fire finder radar so that its operation is safer.

[46] One skilled in the art will understood that even though various embodiments and advantages of the present invention have been set forth in the foregoing

description, the above disclosure is illustrative only, and changes may be made in detail, and yet remain within the broad principles of the invention. It should also be noted that the functions performed by the components ***204-212*** can be combined to be performed by fewer elements or divided and performed by more elements, with the specific division of functionality depending upon the actual components used in the system ***200***. Therefore, the present invention is to be limited only by the appended claims.